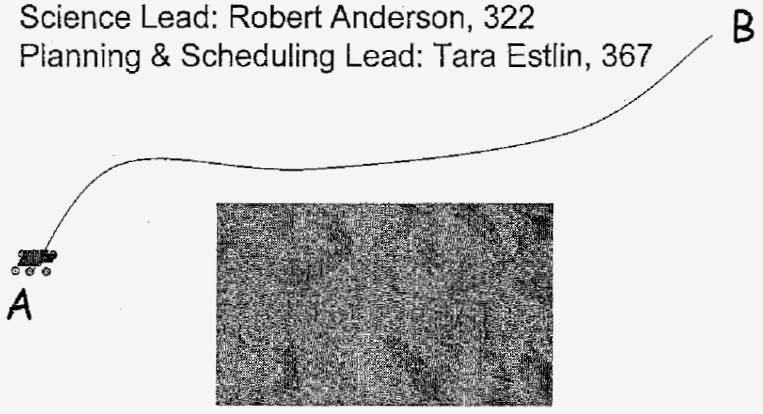
Rover Traverse Science

OASIS Leads

Team Lead: Rebecca Castaño, 367
Science Lead: Robert Anderson, 322
Planning & Scheduling Lead: Tara Estlin, 367



July 23, 2002

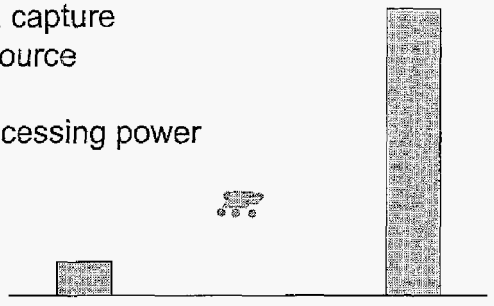
Agenda

Overview of traverse science
Scientific motivation
Technology under development
- Data analysis
- Data prioritization and summary
- Planning and scheduling
- Software validation

Conclusions

What is the Problem?

- Scientists want all the data!
- Rovers are getting larger and driving farther -- thereby creating MORE DATA
- But there are *limited* resources, such as
  - not enough bandwidth to downlink all data that instruments can capture
  - limited DSN resource
  - power
  - storage and processing power



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Solutions?

1) Increase the DSN capability
2) Compress all data
3) Restrict the quantity of data collected
   - Drive but do not collect data!
   - Collect at random times/locations
   - Collect at fixed time/distance intervals
   - Collect at pre-selected locations
4) Intelligently select data for downlink or compression by analyzing science data onboard (prioritization)
5) Summarize data using onboard science data analysis

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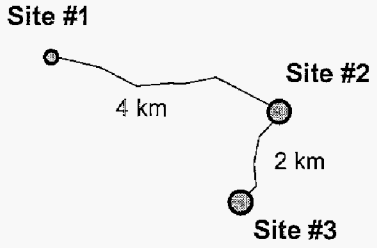
Possible Mission – Overview

Numerous locations to visit which may require a several kilometer traverse between locations



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What is Traverse Science?

Collecting science information while traveling from point A to point B

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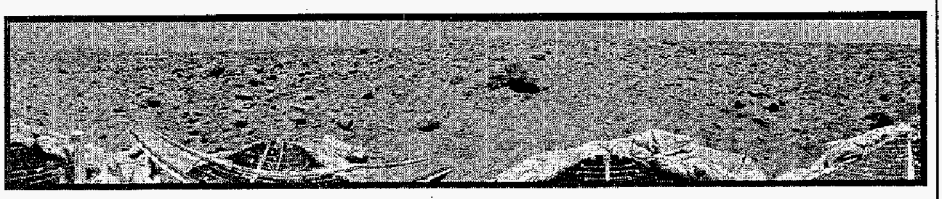
Traverse Science Goals

- Identify pre-specified key targets
  - signs of water
- Identify novel, unexpected objects
- Catalog and summarize terrain covered



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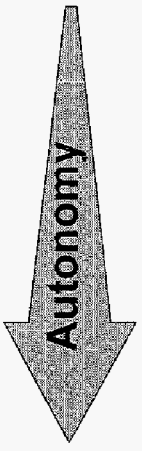
Traverse Science Options



1) Prioritize images (Navcam) collected during traverse for downlink
2) Collect inexpensive extra data of potentially interesting objects
3) Slightly adjust path to get better view of a very interesting object
4) Approach and take contact measurement of an extremely interesting object

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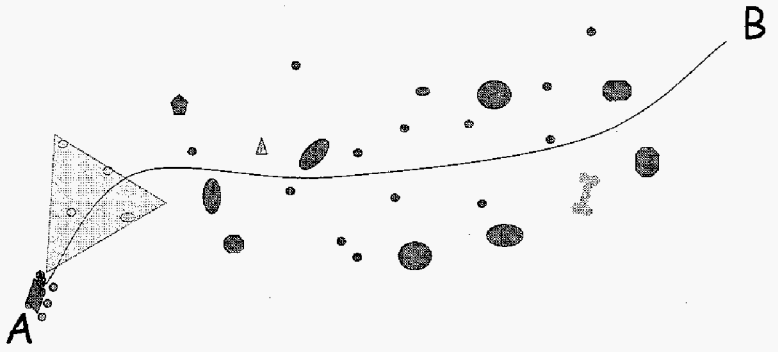
Traverse Science Example



Analyze Navcam images for science targets

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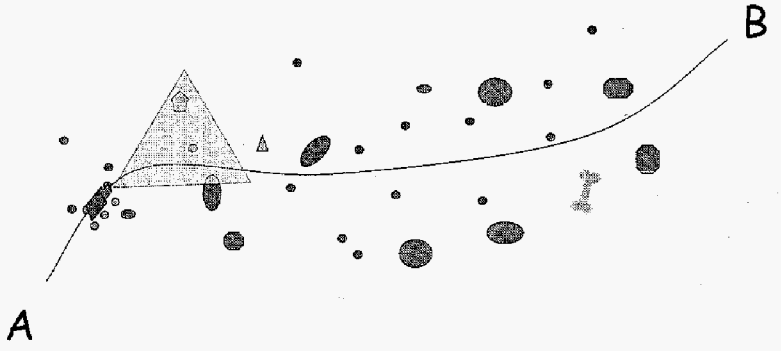
Traverse Science Example



Compile summary information on region

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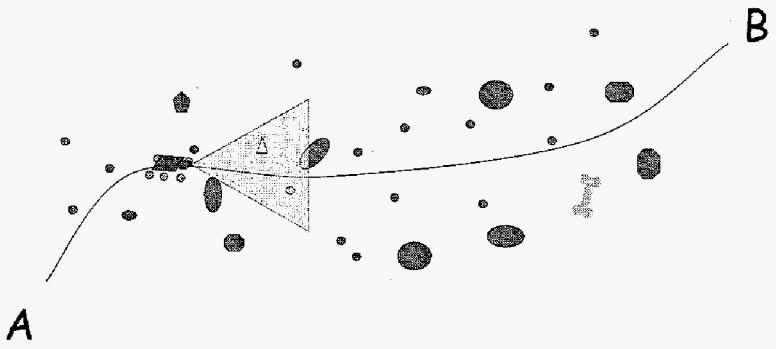
Traverse Science Example



Potentially interesting object detected
-> take a color image

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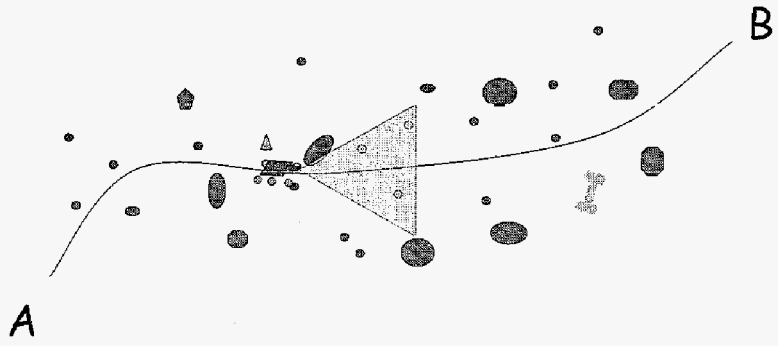
Traverse Science Example



Continue analyzing Navcam images

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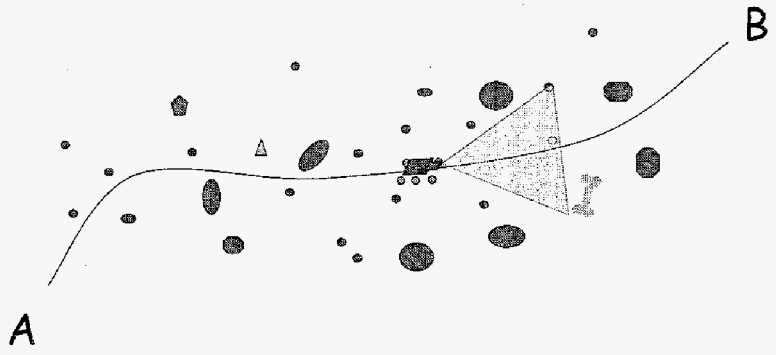
Traverse Science Example



Continue analyzing Navcam images

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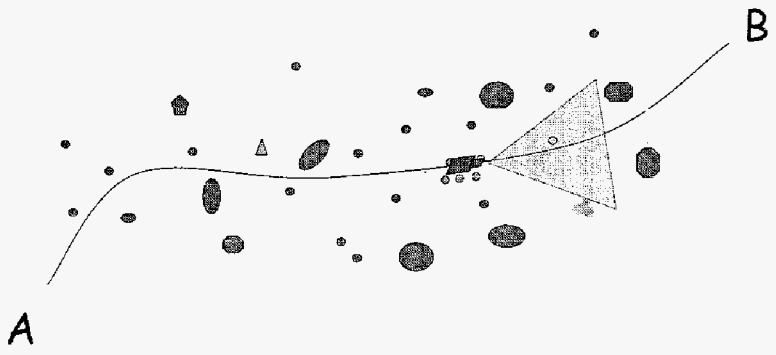
Traverse Science Example



Potentially interesting object detected
-> take a color image or spectrometer measurement

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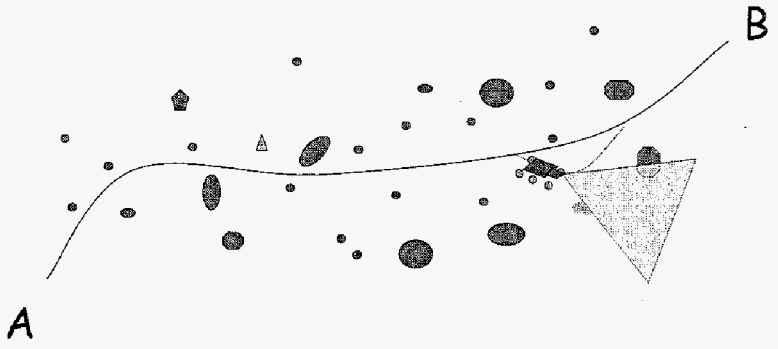
Traverse Science Example



Object appears to be very interesting
-> slightly adjust course to improve view of object

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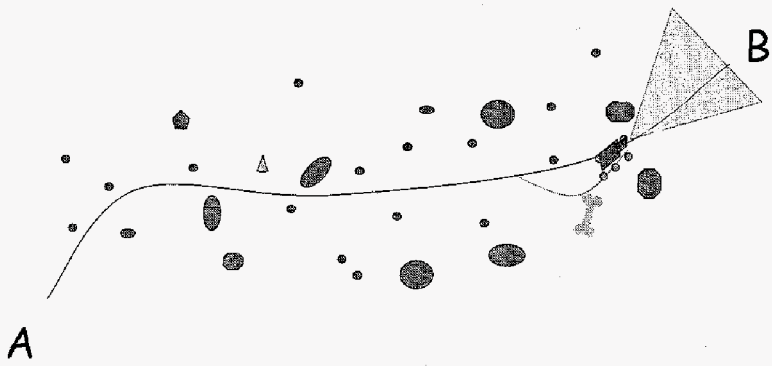
Traverse Science Example



Proceed along path to destination

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Agenda

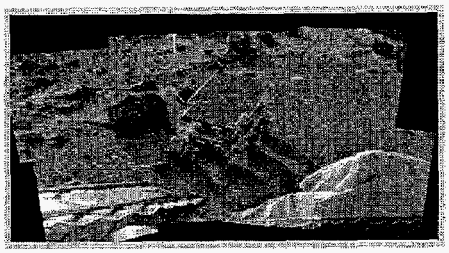
Overview of traverse science scenarios

Scientific motivation

Technology under development

- Data analysis
- Data prioritization and summary
- Planning and scheduling
- Software validation

Conclusions



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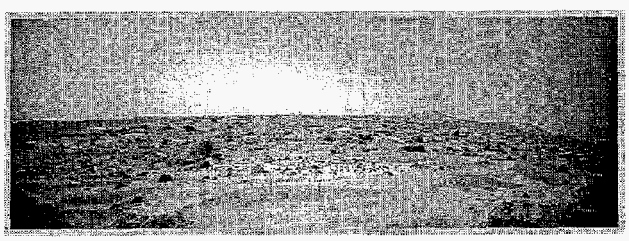
Why Traverse Science?

- Takes a long time to do "science"
- Helps to resolve the conflict between long driving requirements and science - geologists are afraid they are going to miss opportunities for science
- Not trying to replace geologists on the mission
- Increase total mission science return



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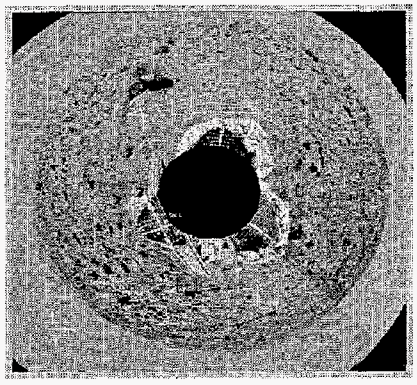
Lessons Learned - MPF



- How to:
  - Land in airbags
  - Drive a rover
  - Navigate a rover on another planet
  - Surface science
- Limited mobility due to line-of-sight communications
- Limited resources --> Limited science return
- The amount of time it takes to "do" science

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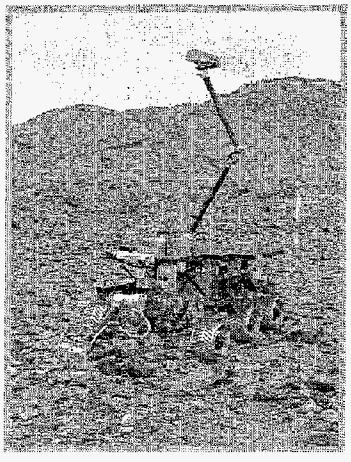
Lessons Learned: 2001 FIDO Field Test

- Can do in-depth science on a small region.
- Meet the minimum science requirements.
- Still have a lot of "dead time" for operations --> Scientist stay in one area too long to maximize science return
- Choose targets based on short traverses.
- Did not meet minimum mission criteria for rover mobility.
- Missed the "Rosetta" stone



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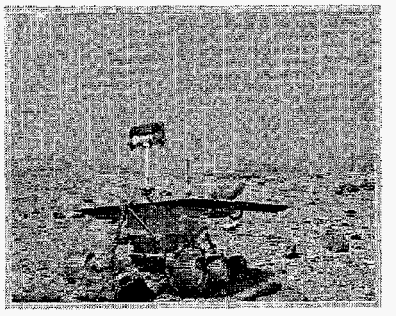
Future Rovers

What about future missions?



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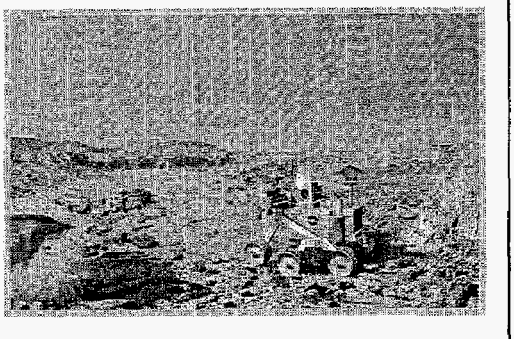

MSL

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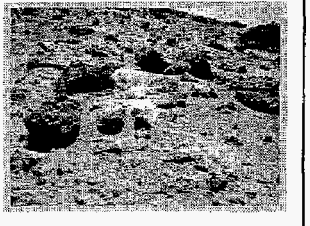
What Can Scientists Learn?

- Identify the "dinosaur bone".
- Chemical compositions, e.g. carbonate detector.
- Separate soils from rocks
- Characterize the variety of rocks/soils
  - texture
  - albedo
  - shape and size
  - color
- Identify the rock distribution
- Characterize local and regional geology
  - how the landscape developed (e.g. fluvial, impact bombardment, aeolian, etc.)
  - the geologic history of the region



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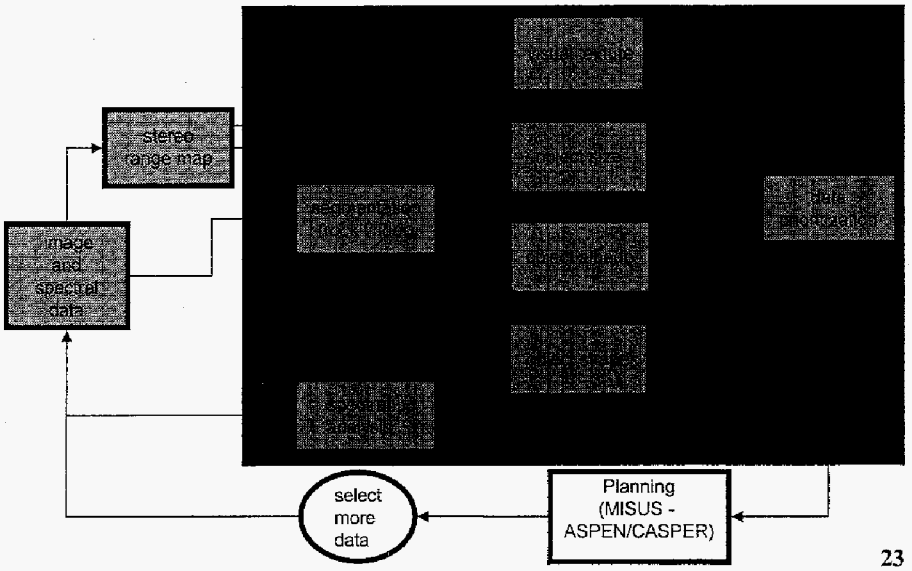
Rover Science Analysis Flow Diagram



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Agenda

- Overview of traverse science scenarios
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- **Technology under development**
  - Data analysis
  - Data prioritization and summary
  - Planning and scheduling
  - Software validation
- Conclusions

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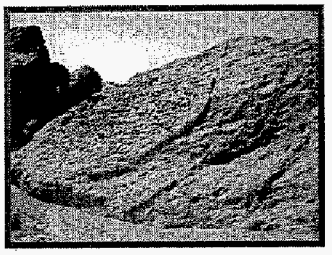
Technology to Achieve this Vision

Data Analysis
- Rock/object identification
- Analysis of individually identified rocks



Data Prioritization and Summary
- Prioritization of data for downlink
- Clustering of rock feature information

Planning and Scheduling
- Command sequence modification
- Resource and state analysis

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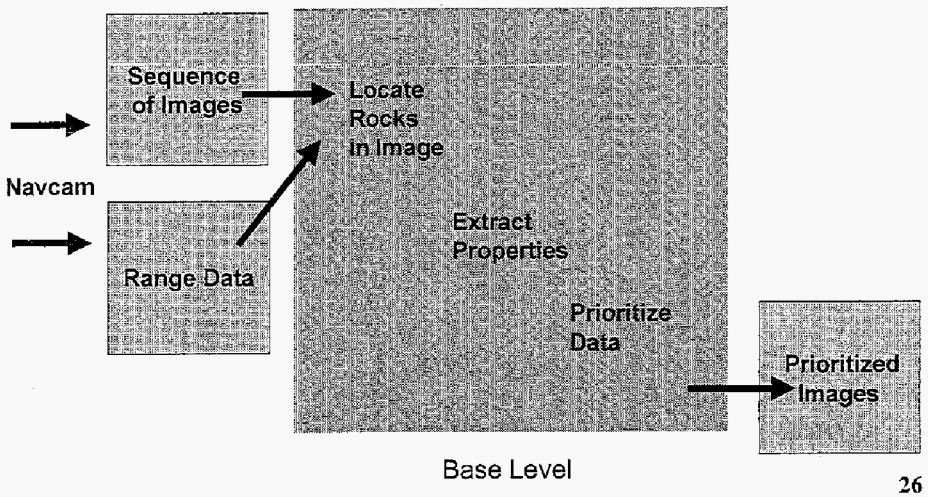
OASIS Science Process



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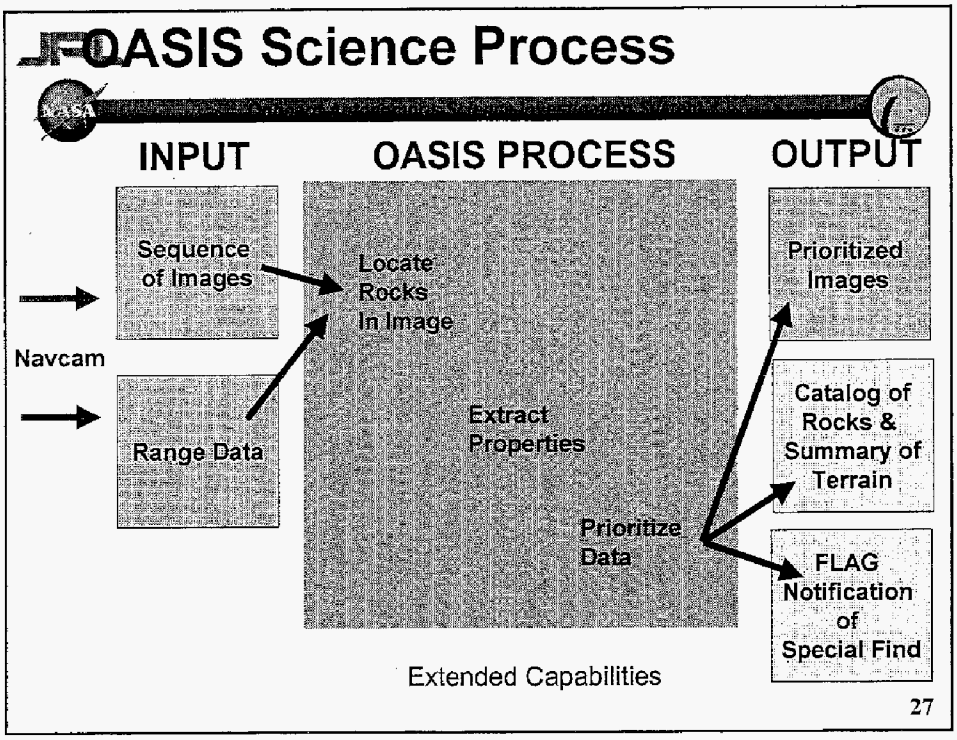
JPL OASIS Science Process
INPUT
OASIS PROCESS
OUTPUT
Sequence of Images
Navcam
Range Data
Locate Rocks In Image
Extract Properties
Prioritize Data
Prioritized Images
Catalog of Rocks & Summary of Terrain
FLAG Notification of Special Find
Extended Capabilities
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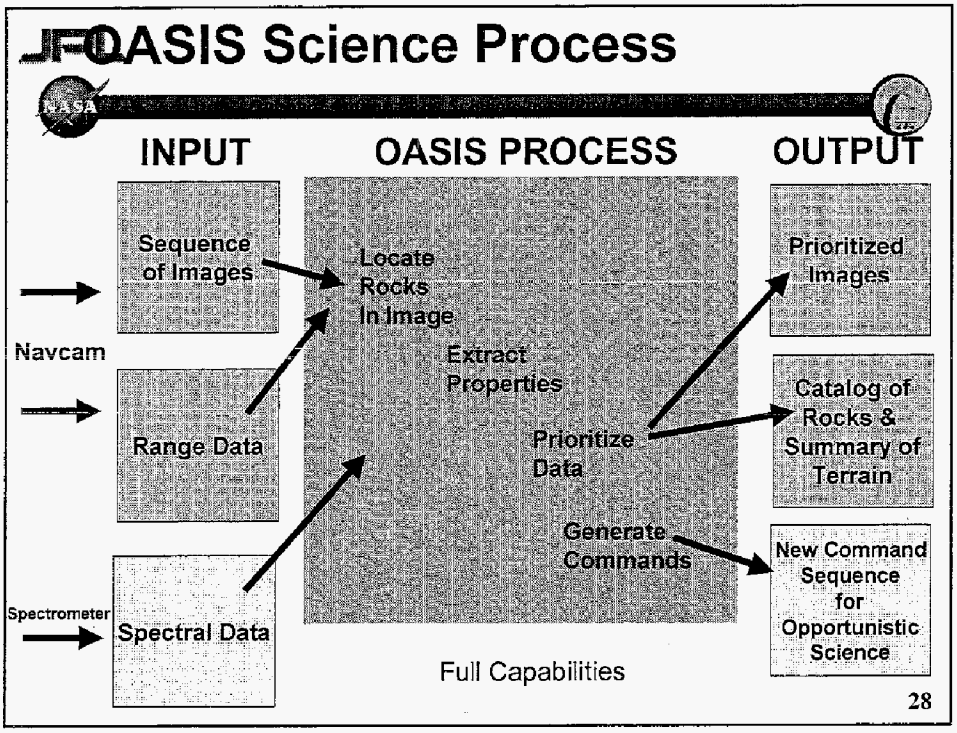
JPL OASIS Science Process
INPUT
OASIS PROCESS
OUTPUT
Sequence of Images
Navcam
Range Data
Spectrometer
Spectral Data
Locate Rocks In Image
Extract Properties
Prioritize Data
Generate Commands
Prioritized Images
Catalog of Rocks & Summary of Terrain
New Command Sequence for Opportunistic Science
Full Capabilities
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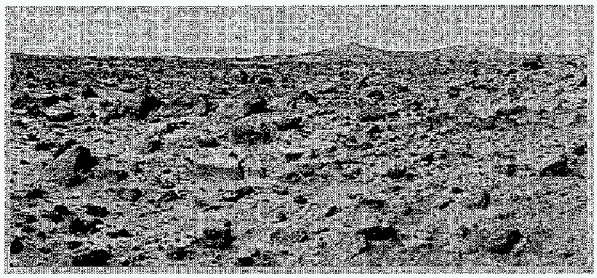
Data Analysis

Science Data Analysis

Spectral Analysis

Image Analysis



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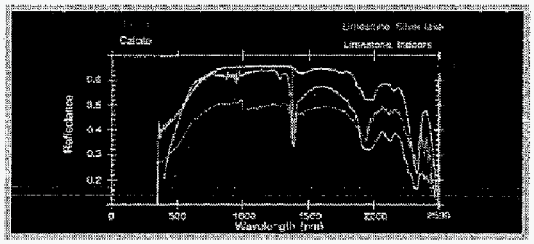
Spectral Analysis



Point spectra

Hyperspectral

Identify presence of minerals in select classes

Spectral images

Multispectral (e.g. color image)

Hyperspectral

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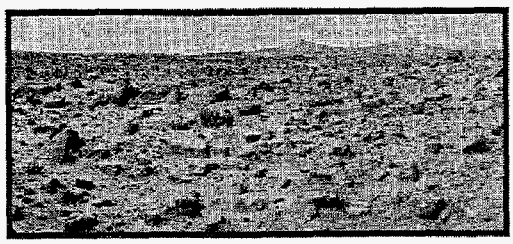
Image Analysis

Rock/Object Detection

Individual Rock Property Analysis

- Texture
- Albedo
- Shape
- Size



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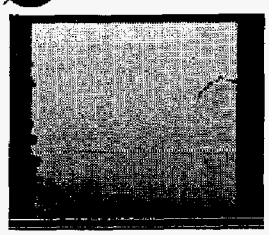
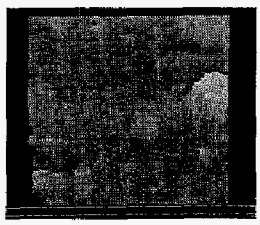
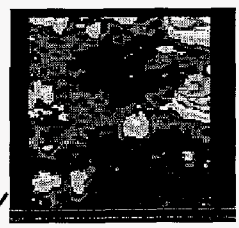
Rock Detection from Range Data



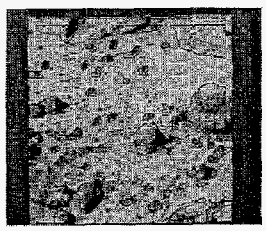
Original range image



Height image



Range-based elementary components



Final rocks

Victoria Gor

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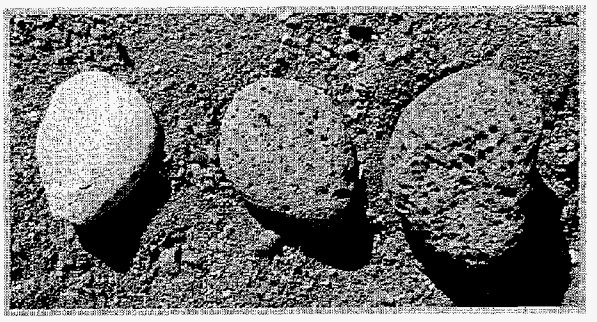
Individual Rock Property Analysis: Texture

Texture classes for surface vesicularity



Smooth Highly vesicular

Visual texture provides information about geologic texture

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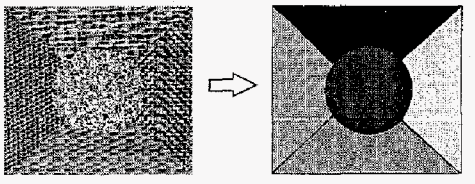
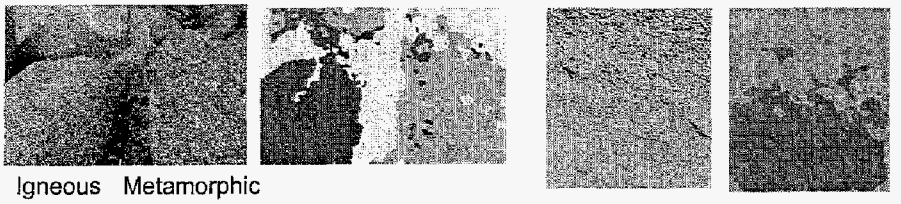
Individual Rock Property Analysis: Texture Segmentation Results

Goal of texture segmentation:



Separate image into homogeneous regions



Igneous rock Metamorphic rock

Sedimentary rock

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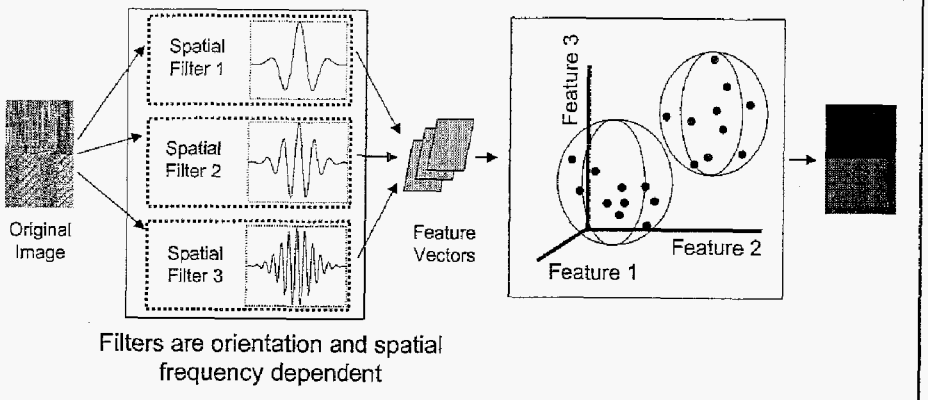
Individual Rock Property Analysis: Texture Analysis Technique



Filters are orientation and spatial frequency dependent

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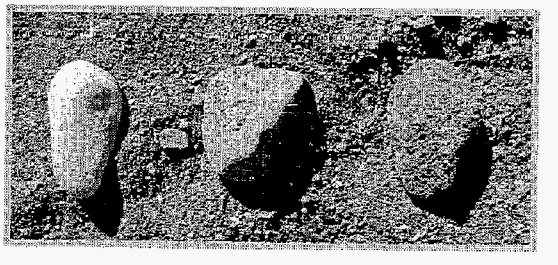
Individual Rock Property Analysis: Albedo



Light Dark

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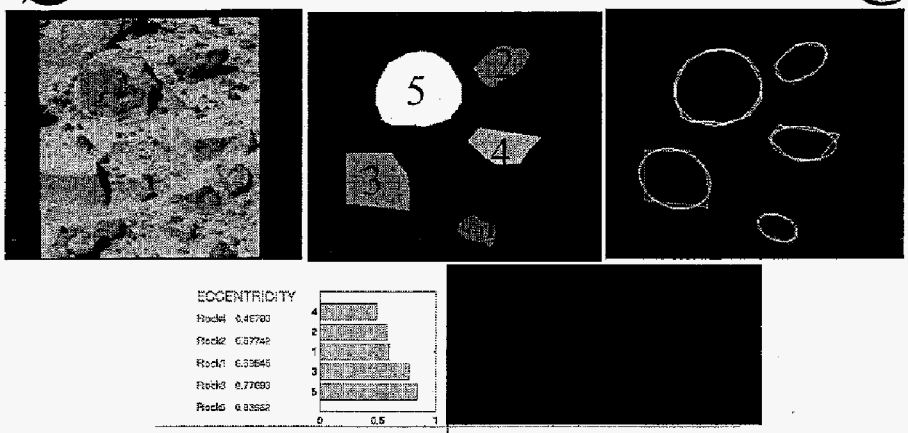
Individual Rock Property Analysis: 2D Shape Analysis



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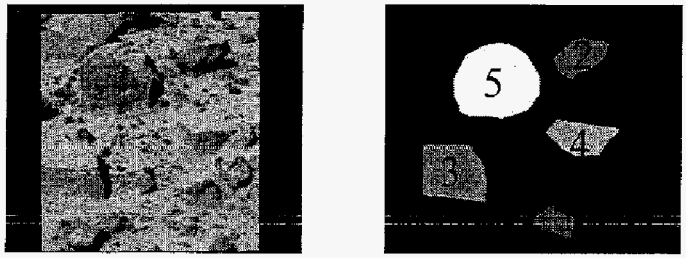
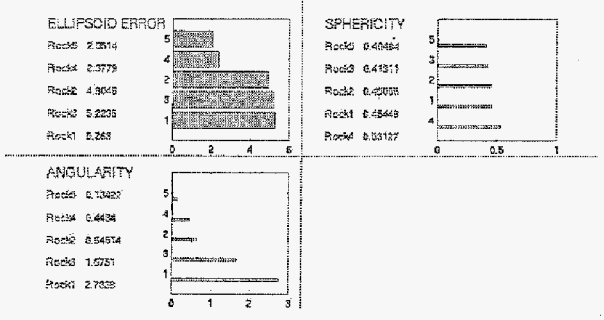
Individual Rock Property Analysis: 3D Shape Analysis





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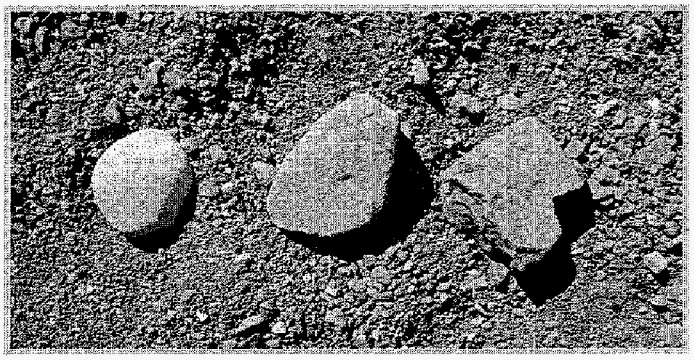
Individual Rock Property Analysis
Shape: Angularity

Angularity classes



Rounded | Sub-rounded/ Sub-angular | Angular

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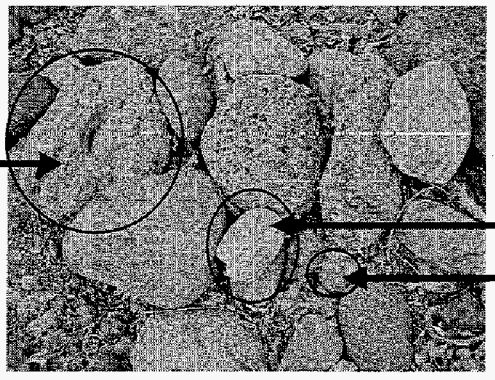
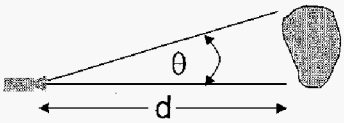
Individual Rock Property Analysis: Size





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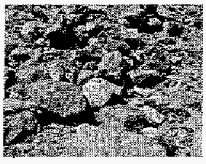
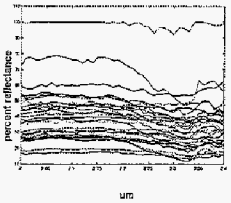
Prioritization – Key signatures

Carbonate Detector

Trained neural network is used to separate rocks containing carbonate minerals from rocks that do not contain carbonate minerals

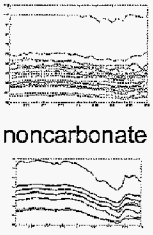


field collection site
Silver Lake, CA



spectrometer measurements

supervised classification (neural net)



noncarbonate

carbonate

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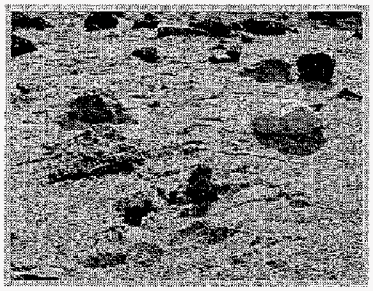
Prioritization - Novelty

Clustering outliers
Cluster all data

Mixture model outlier
Train on all but test rock

One-class discrimination
Train on all but test rock



Dennis Decoste
And
Dominic Mazzoni

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Prioritization – Cataloging

Example data

Unsupervised clustering ensures sampling each class of rock

clustering using albedo and texture

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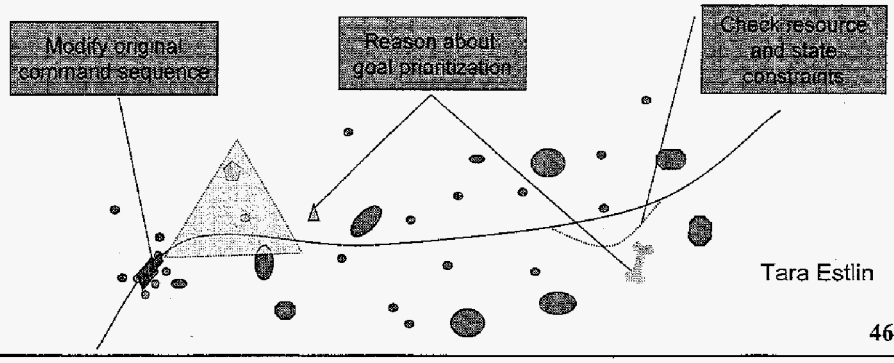
Planning Enabling to Traverse Science

- Applicable for 3 of 4 onboard science options
- Provides capability for adjusting the current command sequence to accommodate new science activities



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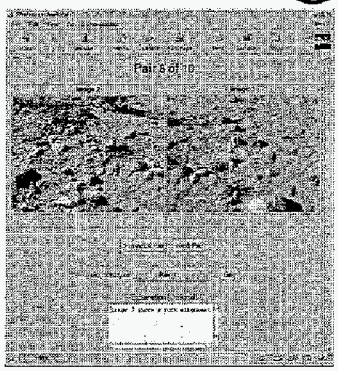
Validation

Compare automated prioritization to expert prioritization of same data

Prioritization compared to ground truth as verified by experts at the field site

Testing data
- Pathfinder
- Mars yard – Rocky 8, FIDO, digital camera
- Field data – FIDO, digital camera, IPS
- Portable stereo platform



GUI for collecting expert ranking of data set

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Agenda

- Overview of traverse science scenarios
- Scientific motivation
- Technology under development
  - Data analysis
    - Spectral analysis
    - Rock detection
    - Rock property extraction
  - Data summary
    - Clustering
    - Prioritization
  - Planning and scheduling
  - Validation
- **Conclusions and Summary**

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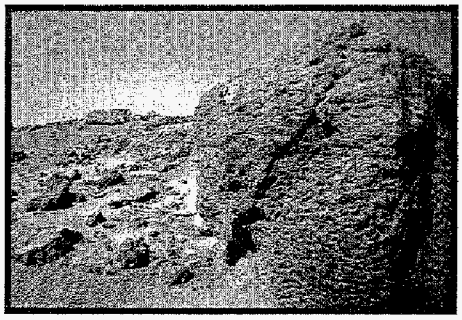
Future Work

- Combine three prioritization methods
- Include spatial information on rock locations
- Expand spectral analysis to new rock classes (sulfates, etc.)
- Expand from point spectral analysis to spectral images
- Data fusion from multiple instruments



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Summary

- Traverse science will
  - Help to resolve the conflict between long driving requirements and science
    - Geologists are afraid they are going to miss opportunities for science.
    - Increase mobility and resource utilization.
  - Increase total mission science return.
  - Not replace geologists on the mission!!!
- Technology advances to enable traverse science are under development

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Current sponsors
- IND (IPN-ISD)
- IS
- CETDP
- Mars Tech

Past sponsors
- REE

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Questions?